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A Recurving Tropical Storm and Perfect Boundary Conditions Regarding the Movable-Area Fine-Mesh Model in the Western Pacific

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This is an unreviewed manuscript, primarily intended for informal exchange of information among NMC staff members.

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ABSTRACT

A special look was taken of Typhoon Gilda, a storm in the Western Pacific which developed into a typhoon during October 1977. The forecasts for this storm by the Movable-Area Fine-Mesh Model (MFM) gave a slower than actual movement as the storm moved north after recurvature. This case compares well to a similar pattern for MFM forecasts of Hurricane Ella in the Atlantic during September 1978. To see if the forecast deviation from the observed track was forecast model dependent or due to the forecast boundary input, a set of perfect boundaries were used. This consisted of setting up the hemispheric analysis as the forecast boundary input to the model, each 12 hours out to 48 hours. In addition, two other typhoons were examined in regard to the influence of boundary conditions on the MFM forecasts of their storm tracks.

1. Background

During the last year an experiment using the National Meteorological Center's (NMC) Movable-Area Fine-Mesh Model (MFM) was run on eight different storms from the Western Pacific -1977 Typhoon Season (Kerlin,1979b).

The forecast results for these cases were good even with some very poor forecasts included in the experiment. Since these storms were located in areas of sparse conventional data (see figures 1 and 2) it was thought that some of the poorer forecasts could have resulted from analysis errors and/or poor boundary conditions from the Hemispheric Primitive Equation Model.

In addition, Typhoon Gilda not only exhibited a large forecast error but appeared to have similar characteristics as Hurricane Ella in the 1978-Atlantic Hurricane Season. This Note provides the results of seven separate forecasts of Typhoon Gilda using the MFM, two cases of Perfect (i.e. analysis) Boundary Conditions for Typhoon Gilda, and one case each for Typhoons Dinah and Jean.

The required northern hemispheric analysis fields were built from the NMC archived data base. These fields were produced by the operational spectral analysis system (Flattery, 1971). When forecast boundaries were used, the 1978 operational version of the hemispheric 6-layer Primitive Equation Model (Shuman and Hovermale, 1968) was run to provide boundary conditions out to 48 hours.

The grid spacing and area of coverage of the MFM as compared with the Hemispheric Primitive Equation Model, Limited-Area Fine-Mesh Regional Model, and the Very Fine-Mesh Precipitation Model is shown in Figure 3.

Once the storm's center location in degrees of latitude and longitude is specified, the MFM then generates a symmetrical horizontal and vertical storm structure. From this structure, a storm forecast is made out to 48 hours using the aforementioned analysis and forecast system. The forecast output of the model consists of the latitude and longitude of the storm's center every six hours out to a 48 hour forecast.

II. Typhoon Gilda

Typhoon Gilda first started out as a tropical depression on the 3rd of October 1977 with a maximum wind of 38 knots (Annual Typhoon Report, 1977). The storm began with a slow north and northwesterly movement and by the 5th of October had central winds observed as high as 80 knots (see Figure 4).

During this same period a mid-tropospheric, short-wave trough had moved eastward from Eastern China toward Japan, and stated to deepen.

By the 5th of October the trough had moved further east and dug equatorward to break the subtropical ridge north of Gilda.

By the afternoon of the 6th, Gilda had a north-northwesterly track toward the weakness in the ridge.

On the 7th of October, the storm passed through the subtropical ridge and shortly thereafter began recurving toward the north-northwest and continued to intensify after recurvature.

During the 8th, the storm began to weaken and on the morning of the 10th, it became extratropical moving toward the east-northeast. There were seven forecasts made in this test on Typhoon Gilda (see Figures 5, 6, and 7). Results were verified against positions provided by the Joint Typhoon Warning Center and documented in the 1977-Typhoon Annual. They are as follows:

Case A. Typhoon Gilda 00Z/05 Oct 77

Hour	Wind (kts)	Forecast Lat/Long	Fix Lat/Long	Vector Error (NM)
00	65	20.6/207.1	20.6/207.1	
06	65	21.1/208.4	21.2/208.2	
12	65	21.8/209.3	21.8/209.0	16.3
18	65	22.5/210.1	22.4/209.7	
24	60	23.2/210.4	23.0/210.3	13.0
30	60	24.1/210.7	23.8/210.8	
36	60	24.9/210.8	24.4/211.3	40.0
42	60	25.7/210.7	25.2/211.8	
48	60	26.6/210.6	26.2/212.3	95.6

Case B. Typhoon Gilda 12Z/05 Oct 77

Hour	Wind (kts)	Forecast Lat/Long	Fix Lat/Long	Vector Error
00	65	21.8/209.0	21.8/209.0	
06	65	22.4/210.2	22.4/209.7	
12	60	23.1/210.9	23.0/210.3	30.5
18	60	23.4/211.2	23.8/210.8	
24	60	24.3/211.4	24.4/211.3	9.2
30	60	25.2/211.6	25.2/211.8	
36	60	26.1/211.7	26.2/212/3	32.1
42	65	26.9/211.6	27.4/212.6	
48	65	27.7/211.5	28.5/212.7	80.0

Case C. Typhoon Gilda 00Z/06 Oct 77

Hour	Wind (kts)	Forecast Lat/Long	Fix Lat/Long	Vector Error
00	60	23.0/210.3	23.0/210.3	
06	60	23.7/210.9	23.8/210.8	
12	60	24.7/211.4	24.4/211.3	20.7
18	60	25.5/211.9	25.2/211.8	
24	60	26.3/212.3	26.2/212.3	5.4
30	65	27.0/212.5	27.4/212.6	
36	65	27.7/212.3	28.5/212.7	53.8
42	65	28.4/211.9	29.7/212.7	
48	70	29.0/211.5	30.9/212.5	124.7

Case D. Typhoon Gilda 12Z/06 Oct 77

Hour	Wind (kts)	Forecast Lat/Long	Fix Lat/Long	Vector Error
00	60	24.4/211.3	24.4/211.3	
06	60	25.2/211.8	25.2/211.8	
12	60	26.6/211.8	26.2/212.3	35.0
18	65	27.6/211.8	27.4/212.6	
24	65	28.4/211.9	28.5/212.7	45.0
30	65	29.2/211.5	29.7/212.7	
36	70	30.2/210.9	30.9/212.5	93.0
42	65	31.1/210.2	32.3/211.8	
48	65	32.0/209.6	33.4/210.7	102.0

Case E. Typhoon Gilda 00Z/07 Oct 77

Hour	Wind (kts)	Forecast Lat/Long	Fix Lat/Long	Vector Error
00	60	26.3/212.1	26.3/212.1	
06	65	27.1/212.4	27.3/212.6	
12	65	28.1/212.2	28.4/212.9	40.4
18	65	28.9/212.1	29.8/213.0	
24	70	29.6/211.7	31.0/212.7	98.9
30	65	30.1/211.3	32.3/211.8	
36	65	30.3/210.8	33.7/210.5	203.0
42	60	30.6/210.3	34.8/209.2	
48	55	30.9/210.0	35.9/208.1	312.5

Case F. Typhoon Gilda 12Z/07 Oct 77

Hour	Wind (kts)	Forecast Lat/Long	Fix Lat/Long	Vector Error
00	65	28.5/212.7	28.5/212.7	
06	65	29.1/212.9	29.7/212.7	
12	70	29.8/212.6	30.9/212.5	65.7
18	65	30.1/212.2	32.3/211.8	
24	65	30.3/211.7	33.4/210.7	193.9
30	60	30.6/211.1	34.5/209.5	
36	55	30.6/210.6	35.9/208.5	336.2
42	50	30.8/210.1	37.3/206.9	
48	45	31.0/209.6	38.7/204.7	520.1

Case G. Typhoon Gilda 00Z/08 Oct 77

Hour	Wind (kts)	Forecast Lat/Long	Fix Lat/Long	Vector Error
00	70	30.9/212.5	30.9/212.5	
06	65	31.5/212.5	32.3/211.8	
12	65	32.6/211.8	33.4/210.7	71.0
18	60	33.3/211.3	34.5/209.5	
24	55	33.7/210.7	35.9/208.5	170.0
30	50	34.1/210.0	37.3/206.9	
36	45	34.4/209.2	38.7/204.7	338.5

The forecast verification results for these cases are summed up below:

TABLE 1

Mean Vector Error (NM)

CASE	12	24	36	48 (HRS)
A. 00Z/05 Oct	16.3	13.0	40.0	45.6
B. 12Z/05 Oct	30.5	9.2	32.1	80.0
C. 00Z/06 Oct	20.7	5.4	53.8	124.7
D. 12Z/06 Oct	35.0	45.0	93.0	102.0
E. 00Z/07 Oct	40.4	98.9	203.0	312.5
F. 12Z/07 Oct	65.7	193.9	336.2	520.1
G. 00Z/08 Oct	71.0	170.0	338.5	-----

The forecasts for the 5th through the 6th of October were on or near the observed track with a maximum error of 124 NM at 48-hours for the forecast based on 00Z/06 Oct data.

As also shown here (Figure 8), the deviation from the observed track increased as the storm began recurvature and rapid movement in the forecasts of Hurricane Ella during 1978 in the Atlantic (Deaven, 1979). The characteristics of the MFM in these two storms (Gilda and Ella) appear to be that as the storm moves north of 30°N, begins recurvature, and rapid acceleration, the MFM indicates recurvature but does not move the storm fast enough along the actual track. Consequently, position forecasts can lag by up to 24 to 30 hours behind the actual positions of the storm.

III. Comparison of MFM Forecasts in the Atlantic and Pacific

The forecast results for all cases in this experiment and the previous experiment (Kerlin, 1979b) are listed below for documentation purposes:

TABLE 2

STORM		Mean Vector Error (NM) 24	36	48 (HRS)
Sarah	12Z/19 July 77	9.5	58.9	137.8
Thelma	12Z/22 July 77	24.8	26.3	118.6
Thelma	12Z/23 July 77	52.1	70.9	80.1
Vera	00Z/29 July 77	116.3	168.2	161.9
Vera	00Z/30 July 77	326.1	340.9	261.4
Babe	12Z/07 Sept 77	117.1	144.6	107.1
Babe	00Z/09 Sept 77	152.2	312.9	-----
Dinah	00Z/15 Sept 77	104.3	133.8	207.5
Dinah	12Z/16 Sept 77	191.8	243.3	301.9
Dinah	12Z/18 Sept 77	30.9	104.4	207.9
Dinah	00Z/20 Sept 77	62.3	85.3	175.4
Dinah	00Z/21 Sept 77	109.8	277.1	366.4
Gilda	00Z/05 Oct 77	13.0	40.0	95.6
Gilda	12Z/05 Oct 77	9.2	32.1	80.0
Gilda	00Z/06 Oct 77	5.4	53.8	124.7
Gilda	12Z/06 Oct 77	45.0	93.0	102.0
Gilda	00Z/07 Oct 77	98.9	203.0	312.5
Gilda	12Z/07 Oct 77	193.9	336.2	520.1
Gilda	00Z/08 Oct 77	170.0	338.5	-----
Ivy	00Z/24 Oct 77	59.3	82.2	113.8
Jean	00Z/29 Oct 77	183.3	208.3	238.4

When these results are compared with forecast verifications of storms in the Atlantic for rich and poor (no land data) data cases using the MFM, the results are comparable as shown below:

TABLE 3

Mean Vector Errors in NM
( ) = Number of Cases

Hours	1976 Atlantic Sparse Data	1977 Western Pacific Cases	1976 Atlantic All Cases	1977 Atlantic All Cases	1976-1978 All OPNL Cases
24	135 (4)	98.8 (21)	126 (14)	95 (11)	96 (63)
36	250 (4)	159.7 (21)	143 (13)	118 (9)	139 (56)
48	365 (4)	196.5 (21)	201 (12)	126 (7)	198 (51)

IV. Perfect Boundary Influence on Typhoon Gilda

To see if the deviation from the observed track was forecast model dependent or due to the initial analysis and forecast boundary input, a set of perfect boundary forecasts were used. This consisted of setting up the hemispheric analysis as the forecast boundary input to the model, each 12-hours out to 48 hours.

The two cases run with perfect boundaries were two of the poorer forecasts in which the MFM forecast moved well away from the observed storm track. The resulting MFM forecasts with perfect boundaries are shown here:

Case E. (Perfect Boundary) Typhoon Gilda 00Z/07 Oct 77

Hour	Wind (kts)	Forecast Lat/Long	Fix Lat/Long	Vector Error (NM)
00	60	26.3/212.1	26.3/212.1	
06	65	26.9/212.6	27.3/212.6	
12	65	27.9/212.7	28.4/212.9	35.5
18	65	28.7/212.7	29.8/213.0	
24	70	29.3/212.8	31.0/212.7	99.4
30	65	29.8/212.9	32.3/211.8	
36	65	30.5/212.9	33.7/210.5	209.5
42	60	31.1/212.9	34.8/209.2	
48	55	31.8/212.6	35.9/208.1	323.3

Use of perfect boundaries in the above case moved the forecast track nicely back to the observed track (see Figure 9). However, the northern movement of the storm along the track was still lagging by 18 to 24 hours behind the observed positions.

Case F. (Perfect Boundary) Typhoon Gilda 12Z/07 Oct 77

Hour	Wind (kts)	Forecast Lat/Long	Fix Lat/Long	Vector Error (NM)
00	65	28.5/212.7	28.5/212.7	
06	65	29.1/212.9	29.7/212.7	
12	70	29.6/213.1	30.9/212.5	83.3
18	65	29.8/213.4	32.3/211.8	
24	65	30.1/213.7	33.4/210.7	249.9
30	60	30.4/213.9	34.5/209.5	
36	55	30.7/213.7	35.9/208.5	404.8
42	50	31.0/213.4	37.3/206.9	
48	45	31.2/213.0	38.7/204.7	604.0

In Case F the use of an analysis boundary gave an interesting result (see Figure 10). The MFM forecast with hemispheric forecast boundary conditions had a definite movement to the right of the actual track. Whereas, with the analysis boundary, the forecast moved the storm off to the left of the track and then recurved it back toward the actual track.

In this case as is the previous case, the use of different boundary conditions certainly had a large effect on forecast movement, with the analysis boundary cases keeping the forecast on track but very slow in its northward movement. In this Case F the 12 hour actual position was near the 48-hour forecast position.

In summary, as shown above, the use of the perfect boundaries did move the forecast track back toward the observed track. Slow movement was still found in the northern movement of the storm after recurvature at higher latitudes and its cause is uncertain. Candidates are the vortex-scale analysis and/or the model grid.

V. Other Perfect Boundary Tests

Two other cases of perfect boundaries were examined for Typhoon Jean and Typhoon Dinah.

Typhoon Jean (see Figure 11) was of interest as it was a very weak storm (Annual Typhoon Report - 1977) and established a record as the shortest-lived typhoon of the season (6 hours).

According to the Annual Typhoon Report -- 1971, "Past analysis revealed that beyond the 30/0000Z position Jean began to react to the effects of very strong vertical shear. At the surface and at low-tropospheric levels, steering flow was strong easterly around the southern periphery of the subtropical ridge. Steering flow at mid-and-upper-tropospheric levels was strong west-southwesterly. Jean began to weaken and had made her furthest northwestward incursion by 1200Z on the 30th with 55 kt intensity. Satellite data on the 30th showed an exposed low-level circulation center to the west of the area of major convective activity. Jean then began to weaken rapidly and move west and then west-northwest in response to the east/east-southeasterly steering at low tropospheric levels."

The forecast track (see Kerlin, 1979 b), observed track, and perfect boundary tracks for Typhoon Jean based on a 48-hour forecast from 00Z/24 October 77 are shown in Figure 12. In this case both the forecast boundary and perfect boundary MFM forecasts were very poor and completely off track. The input analyses appear to be consistently off and apparently missed the important features completely. Further study is needed to explain this case whose data were as follows:

(Perfect Boundary) Typhoon Jean 00Z/29 October 77

Hour	Wind (kts)	Forecast Lat/Long	Fix Lat/Long	Vector Error (NM)
00	40	20.2/203.9	20.2/203.9	
06	50	20.4/204.4	20.9/203.8	
12	60	20.7/204.7	21.5/203.4	88.1
18	65	20.8/205.1	22.1/202.8	
24	65	21.1/205.3	22.7/202.5	230.6
30	60	21.5/205.7	23.2/202.5	
36	55	21.8/206.1	23.6/202.9	377.8
42	50	22.1/206.8	23.9/203.3	
48	45	22.4/207.7	24.1/203.8	517.8

Likewise, Typhoon Dinah (see Figure 13) for the 21st of September was run with forecast boundaries (see Kerlin, 1979b) and with perfect boundaries as shown in Figure 14. The forecast using boundary inputs from the Hemispheric Primitive Equation forecast model was very poor with a northwesterly track being forecast while a southwest track actually occurrred.

This southerly track by Dinah was due to the advancing of a mid-latitude trough over China that did not dig south as might be expected and a large high pressure area behind it. "In response, Dinah did not continue eastward in advance of the trough; it slowed to 2 kts, turned eastward, then southwestward being influenced by the intensifying high over China and an early autumn surge in the northeast monsoon" (Annual Typhoon Report, 1977).

As shown in Figure 14 and the data below, the use of perfect (analysis) boundaries pulled the storm nicely back to the storm track. However, the forecast speed of the model was still slower than the actual speed of the storm. Large-scale analyses are a big source of the error but other sources cannot be ignored.

(Perfect Boundary) Typhoon Dinah 00Z/21 September 77

Hour	Wind (kts)	Forecast Lat/Long	Fix Lat/Long	Vector Error (NM)
00	65	20.2/241.5	20.2/241.5	
06	65	19.8/241.7	20.3/241.8	
12	60	19.5/242.1	20.0/242.7	45.2
18	55	18.9/242.6	19.4/243.5	
24	50	18.3/242.9	18.5/244.5	94.0
30	50	17.9/243.4	17.8/245.1	
36	45	17.7/243.8	17.3/246.3	145.1
48	40	17.3/244.8	15.5/248.0	211.1

VI. Summary

A special look was taken of Typhoon Gilda, a storm in the Western Pacific which developed into a Typhoon during October 1977. The forecasts for this storm by the MFM gave a slower than actual movement as the storm moved north after recurvature. This case was similar to the MFM forecasts of Hurricane Ella in the Atlantic during September 1978.

To see if forecast deviation from the forecast track was MFM model dependent or due to the forecast boundary input, a set of perfect boundaries were used. This consisted of setting up the hemispheric analyses as the forecast boundary input to the MFM, each 12 hours out to 48 hours.

The use of these perfect boundaries for two cases for Typhoon Gilda did move the forecast track back toward the actual track. Slow movement was still found in higher latitudes and its cause is uncertain. Candidates are the vortex-scale analysis or the model grid.

The perfect boundary test was made for Typhoon Jean. In this case the use of analysis boundaries did not improve the track forecast and further study is needed to explain this case.

Typhoon Dinah for the 21st of September was also run with perfect boundaries. Use of analysis boundaries pulled the storm nicely back to the storm track. However, the forecast speed of the model was still slower than observed.

It appears that the large scale analysis may be a big source of the MFM forecast error but other sources cannot be ignored.

Acknowledgement

Dr. Robert E. Livezey provided a great deal of assistance, guidance, and encouragement in the conduct of this project.

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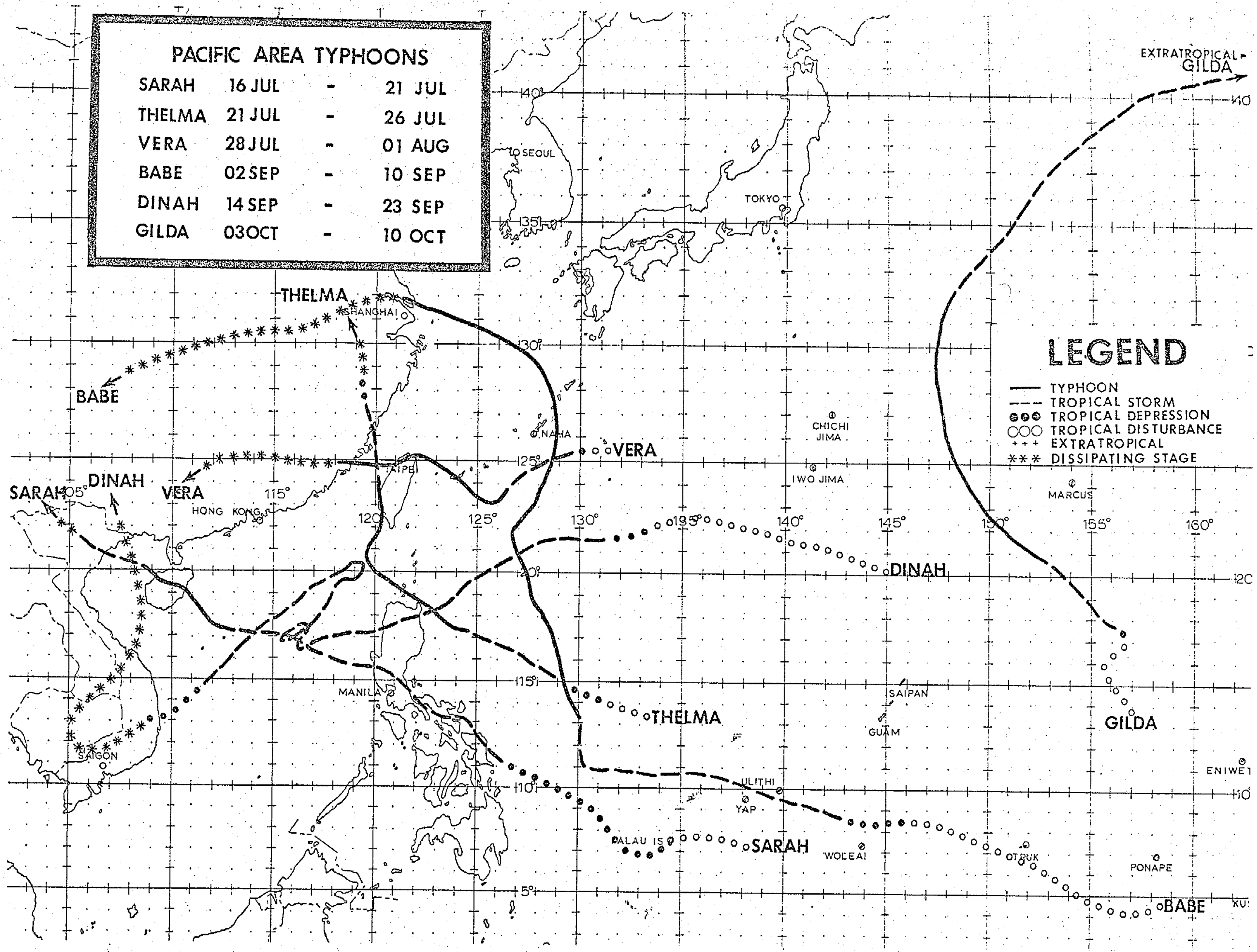

FIGURE 1. (Reference page 16, Annual Typhoon Report - 1977)

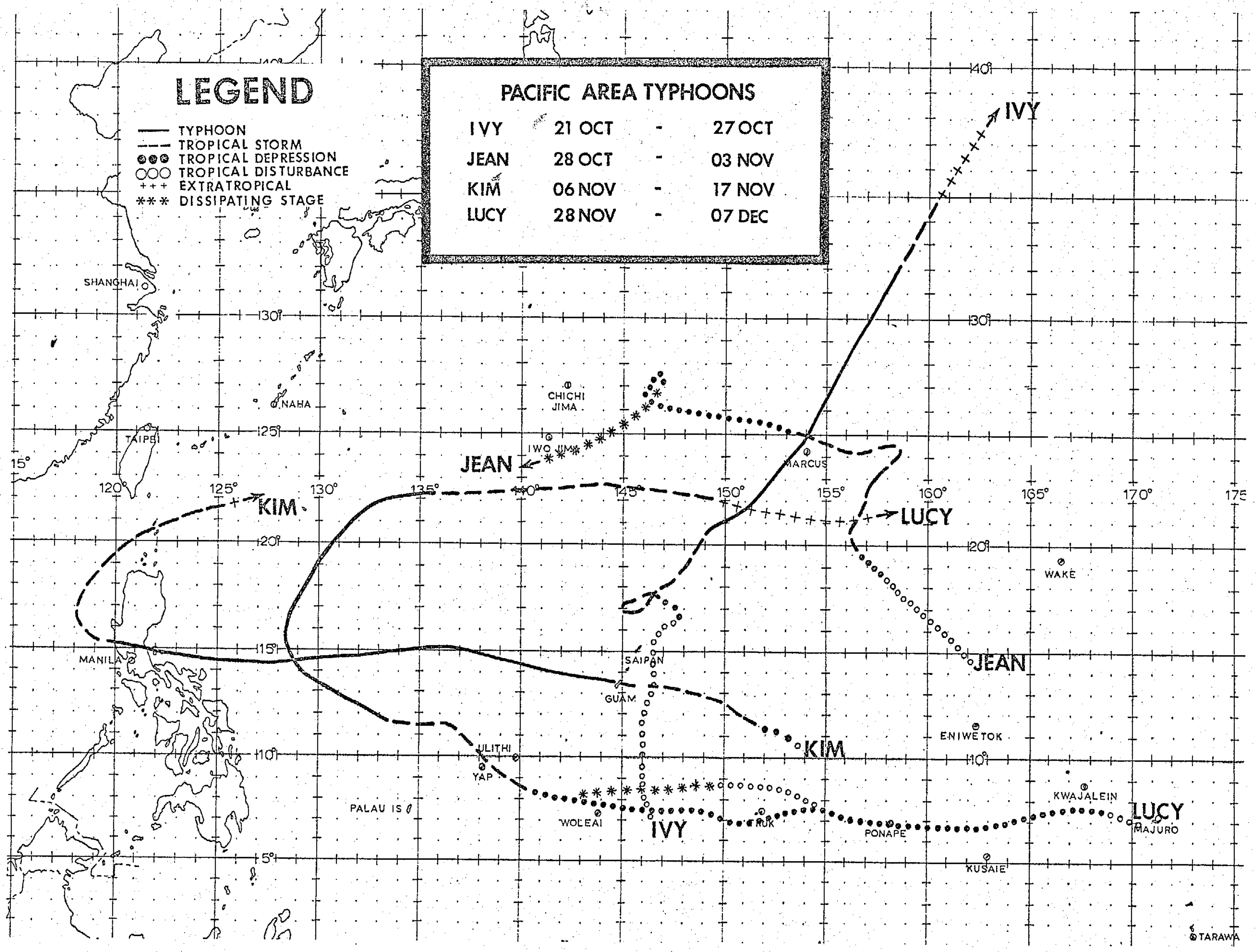

FIGURE 2. (Reference page 17, Annual Typhoon Report - 1977)

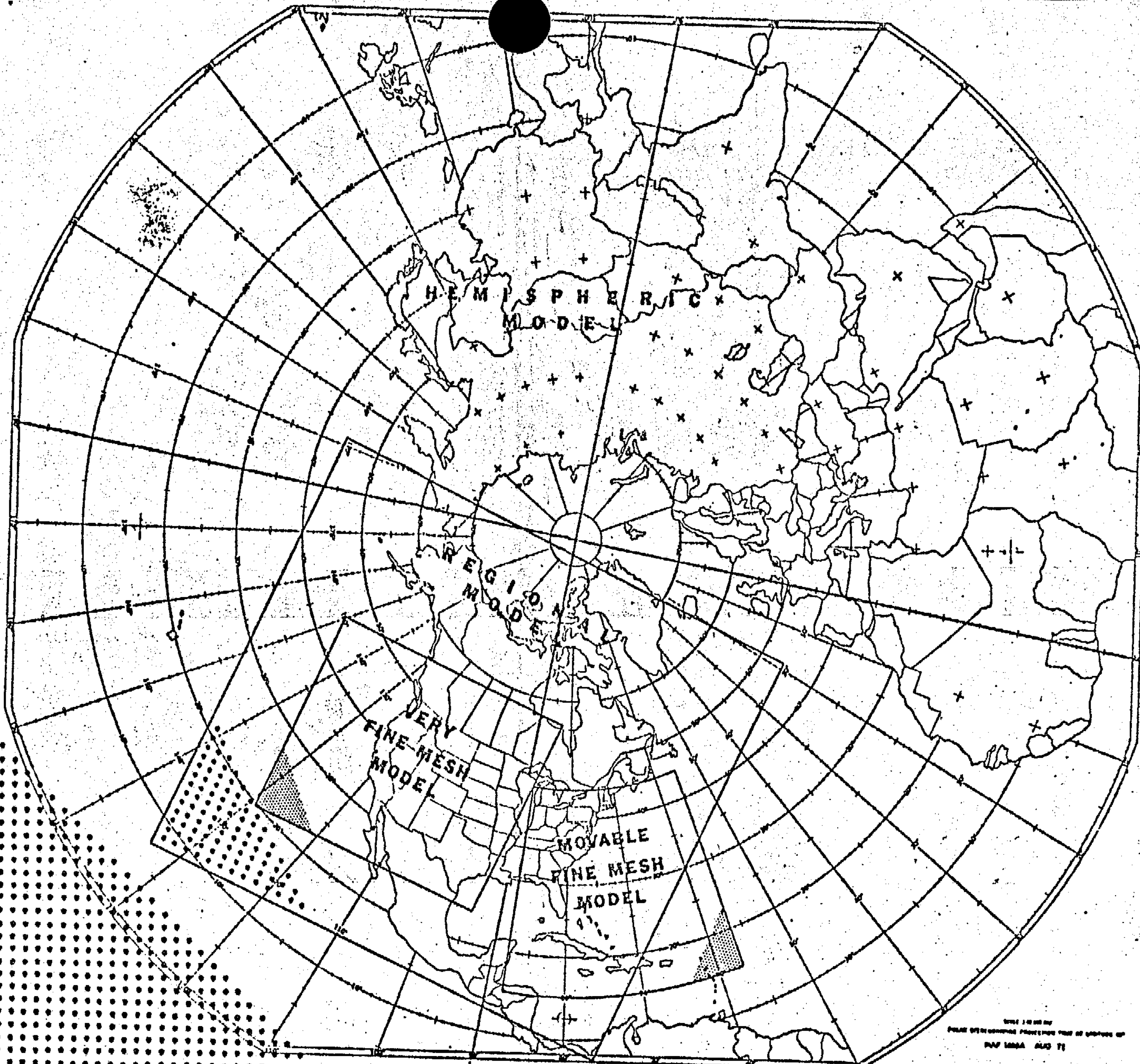

FIGURE 3. Model Grids

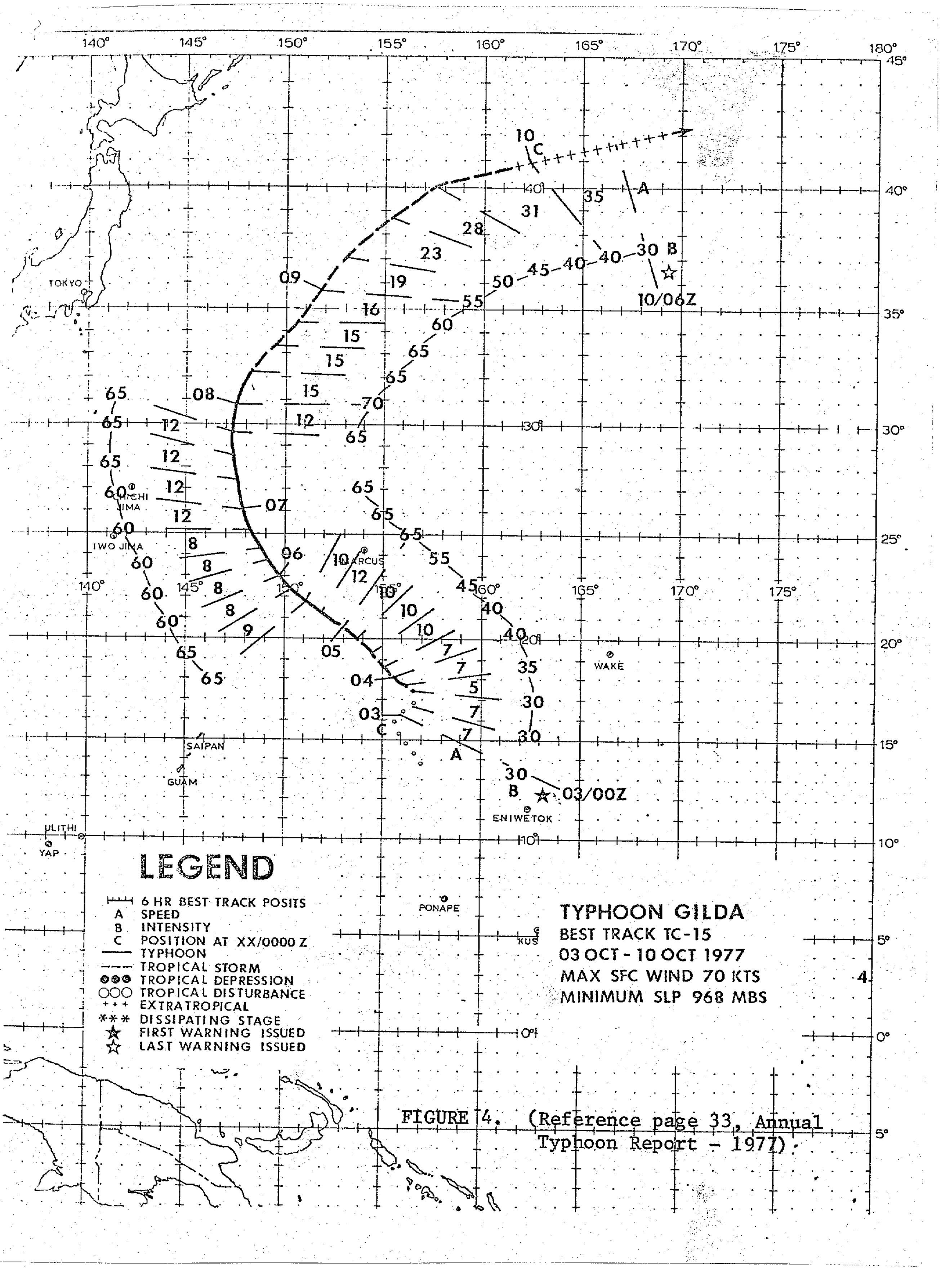

FIGURE 4. (Reference page 33, Annual Typhoon Report - 1977).

4.

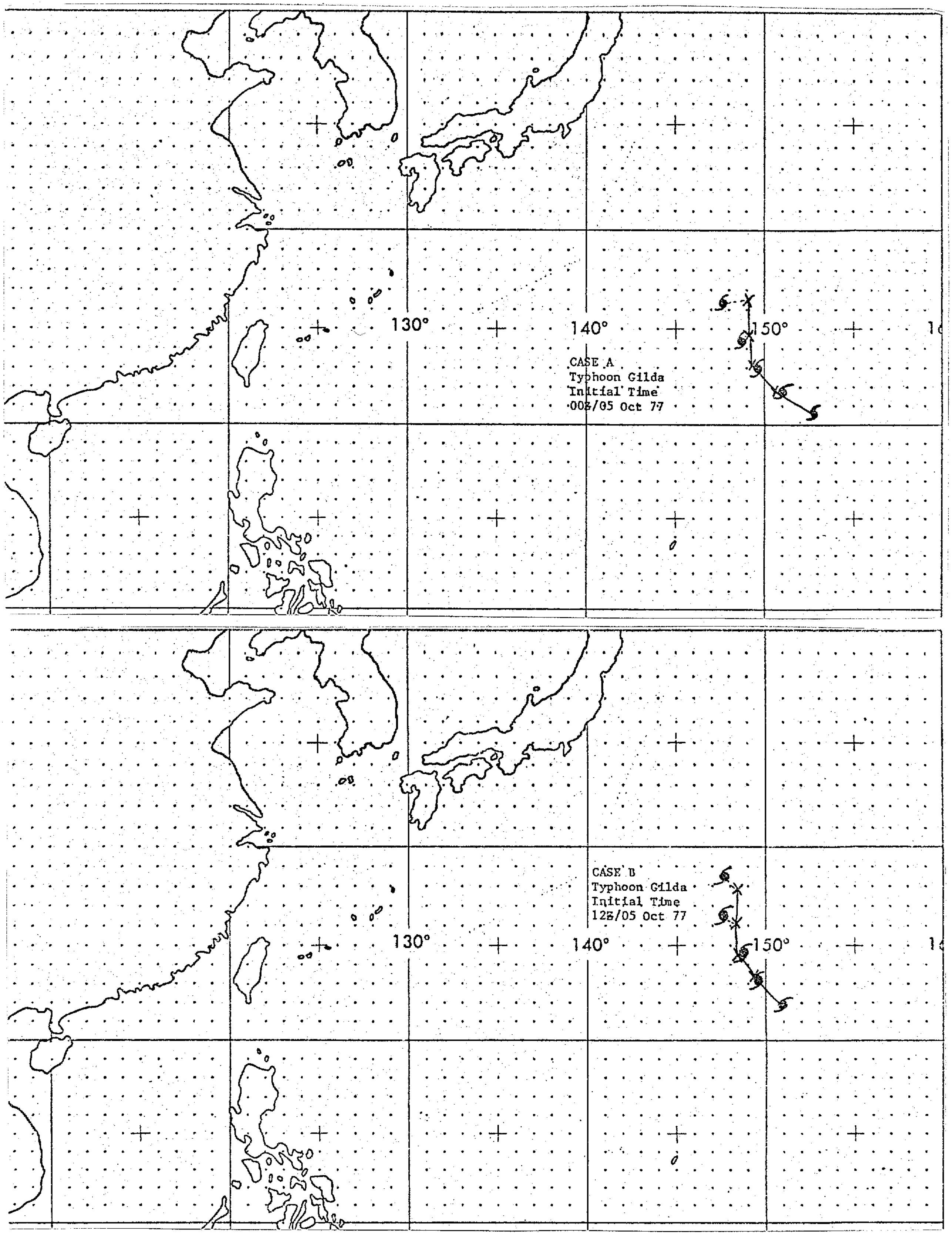

FIGURE 5. Forecasts (x's) and observed (typhoon symbols) for 12-hour intervals.

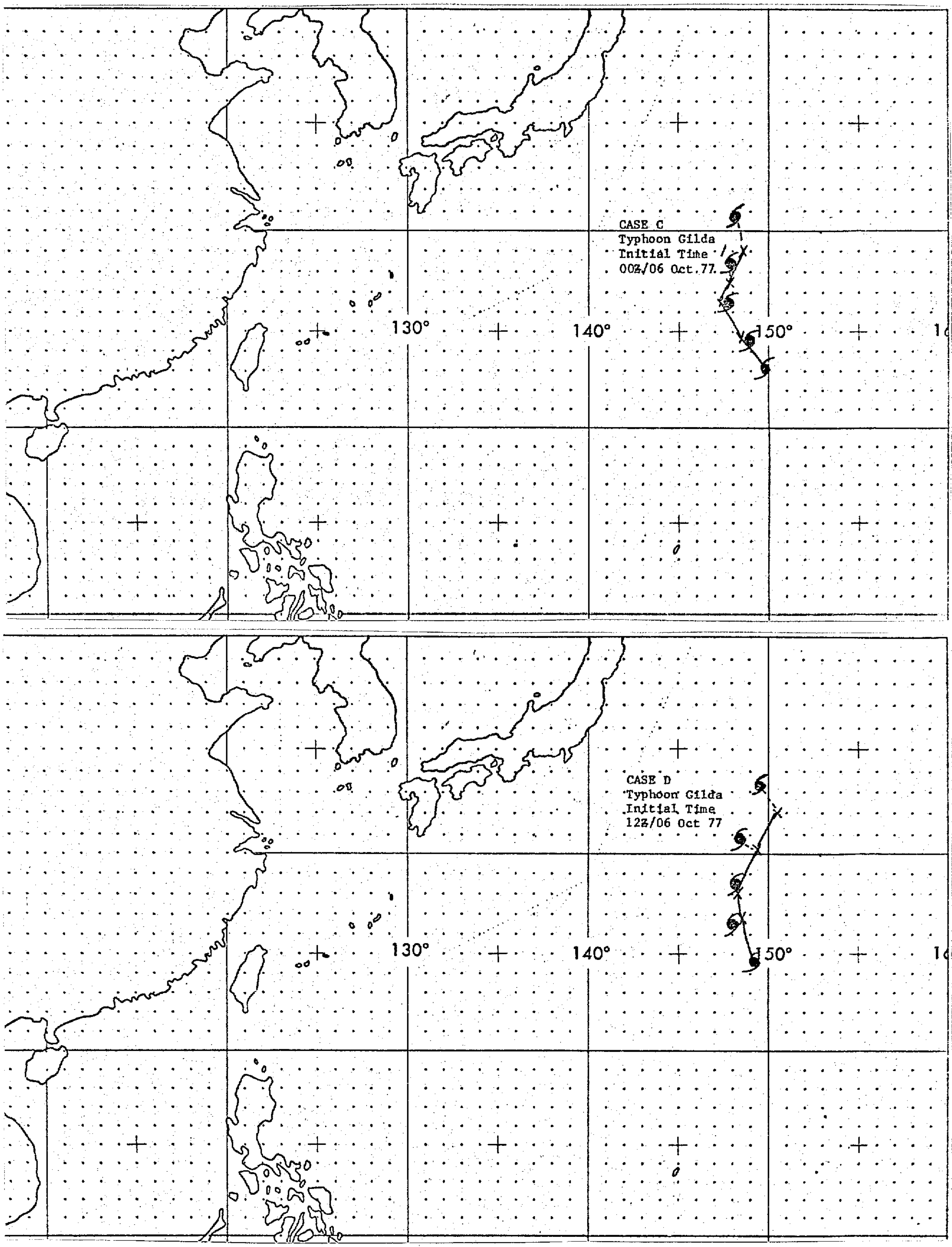

FIGURE 6. Forecasts (x's) and observed (typhoon symbols) for 12-hour intervals.

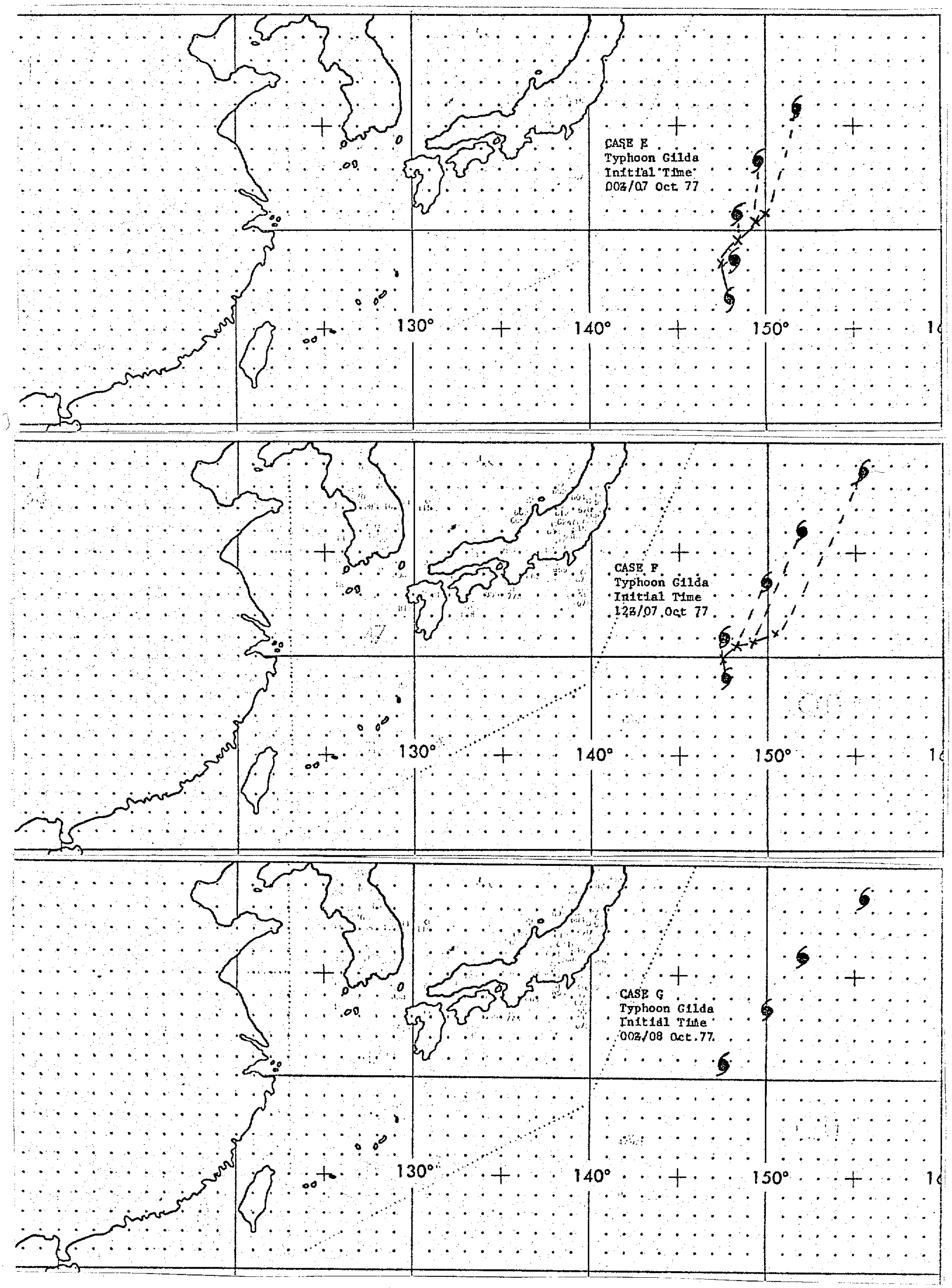

FIGURE 7. Forecasts (x's) and observed (typhoon symbols) for 12-hour intervals.

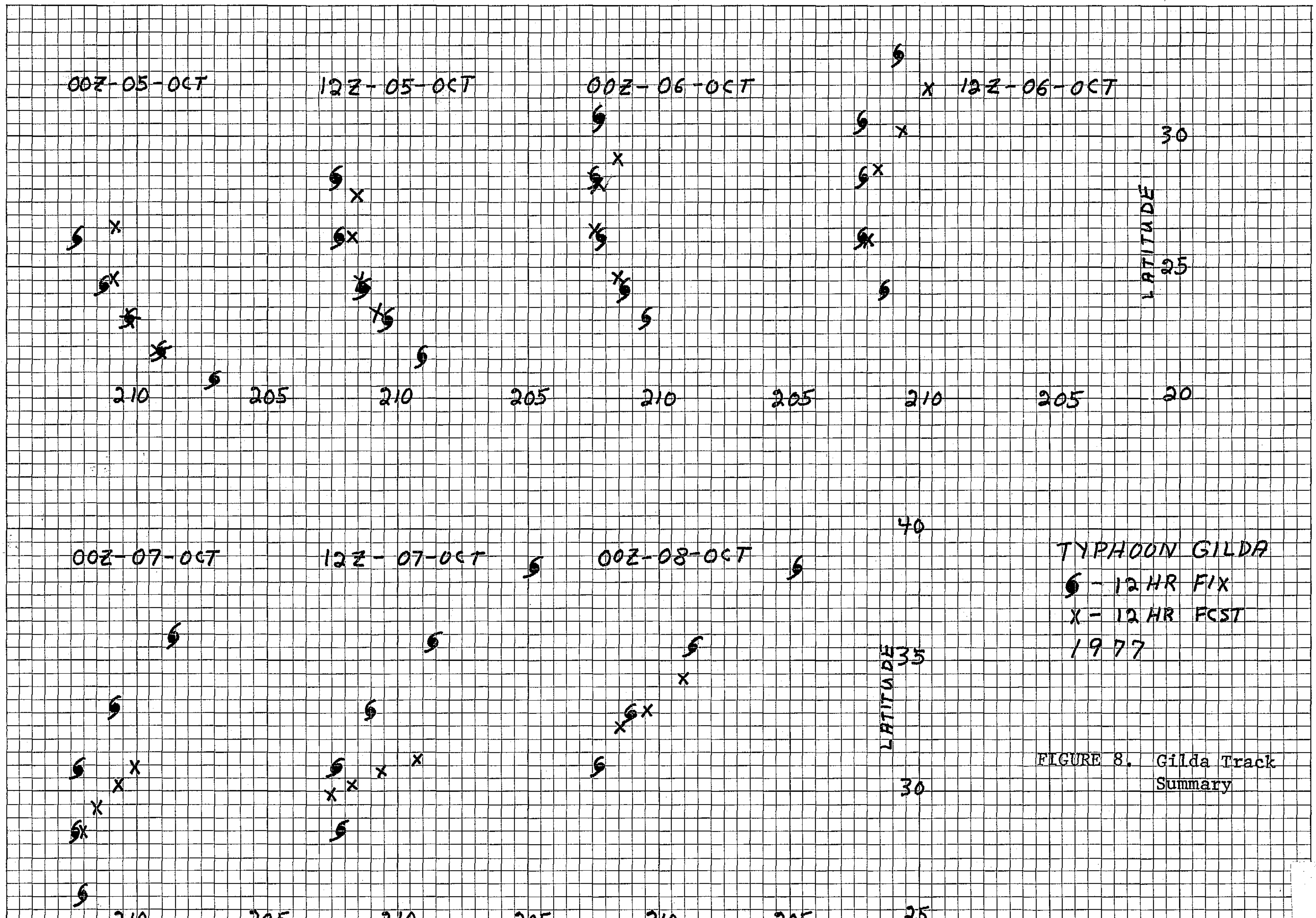

FIGURE 8. Gilda Track Summary

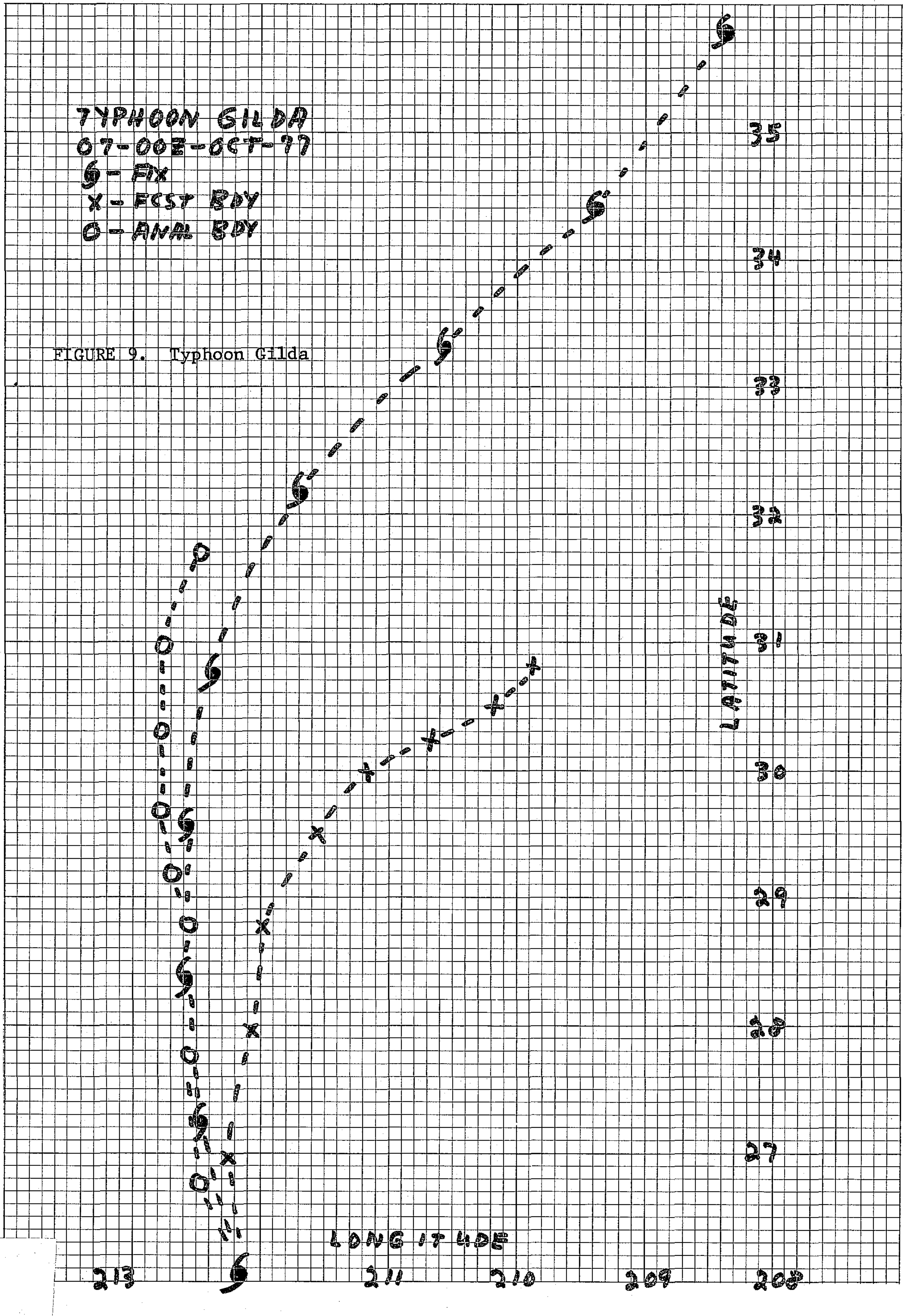

FIGURE 9. Typhoon Gilda

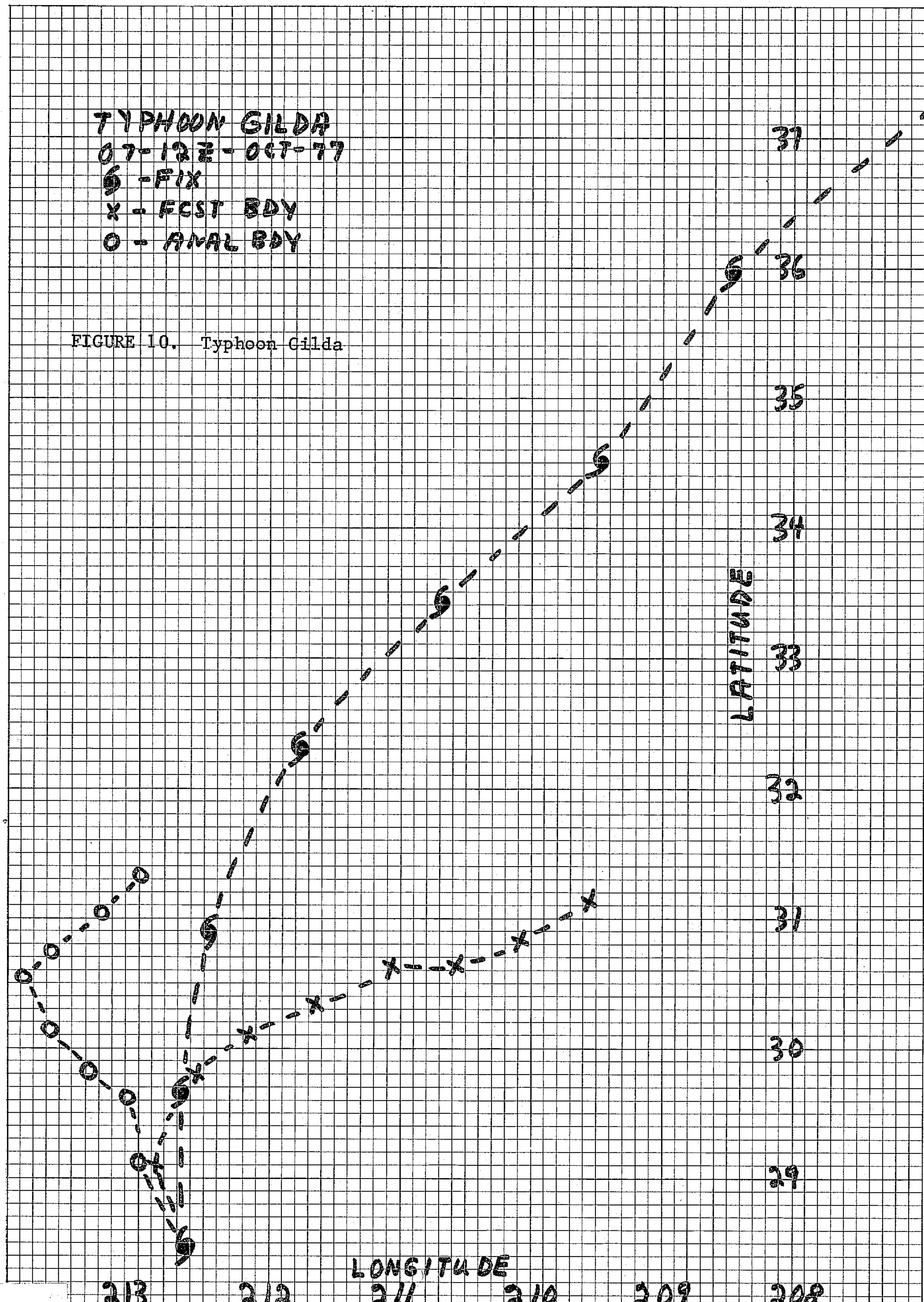

FIGURE 10. Typhoon Gilda

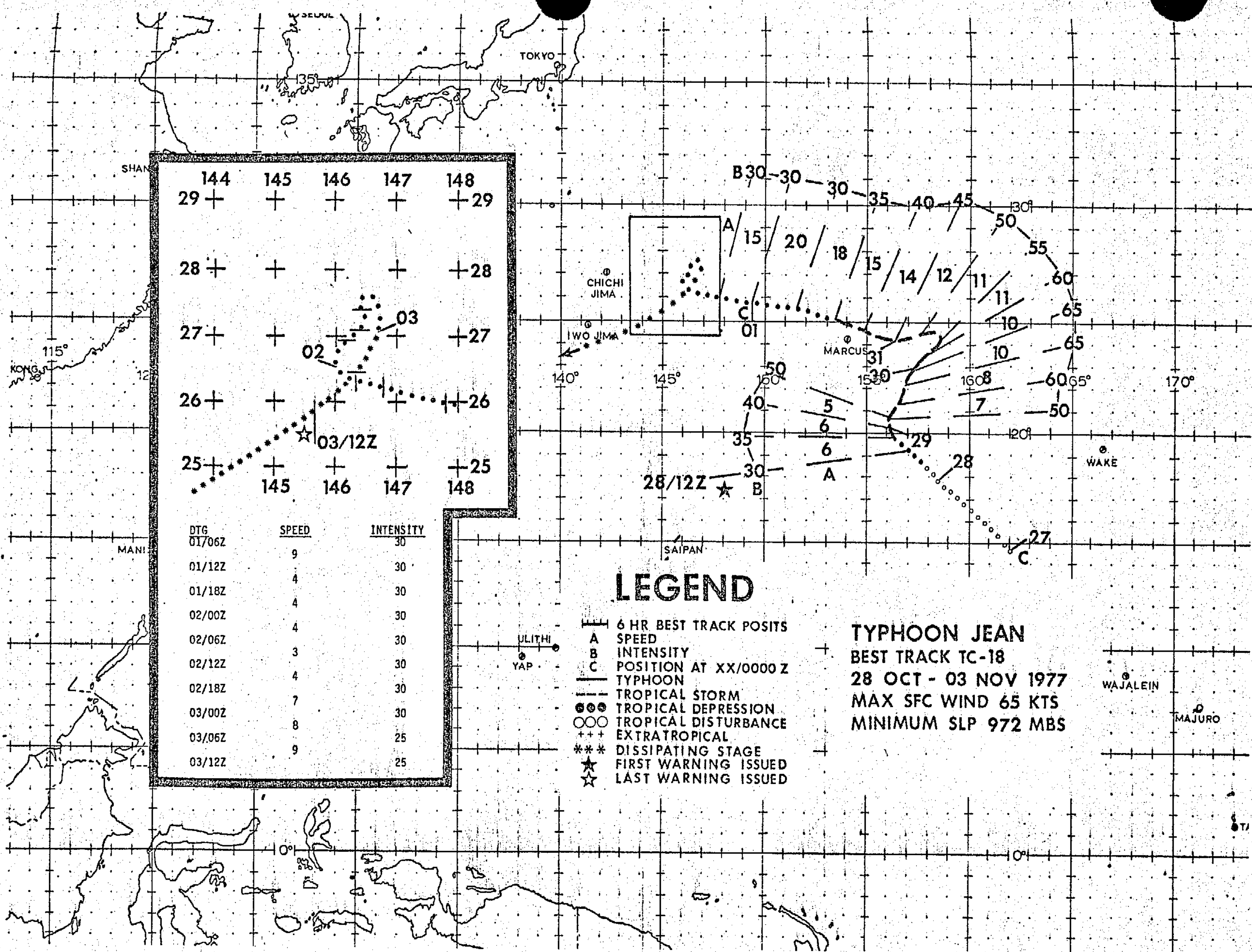

FIGURE 11. (Reference page 38, Annual Typhoon Report - 1977)

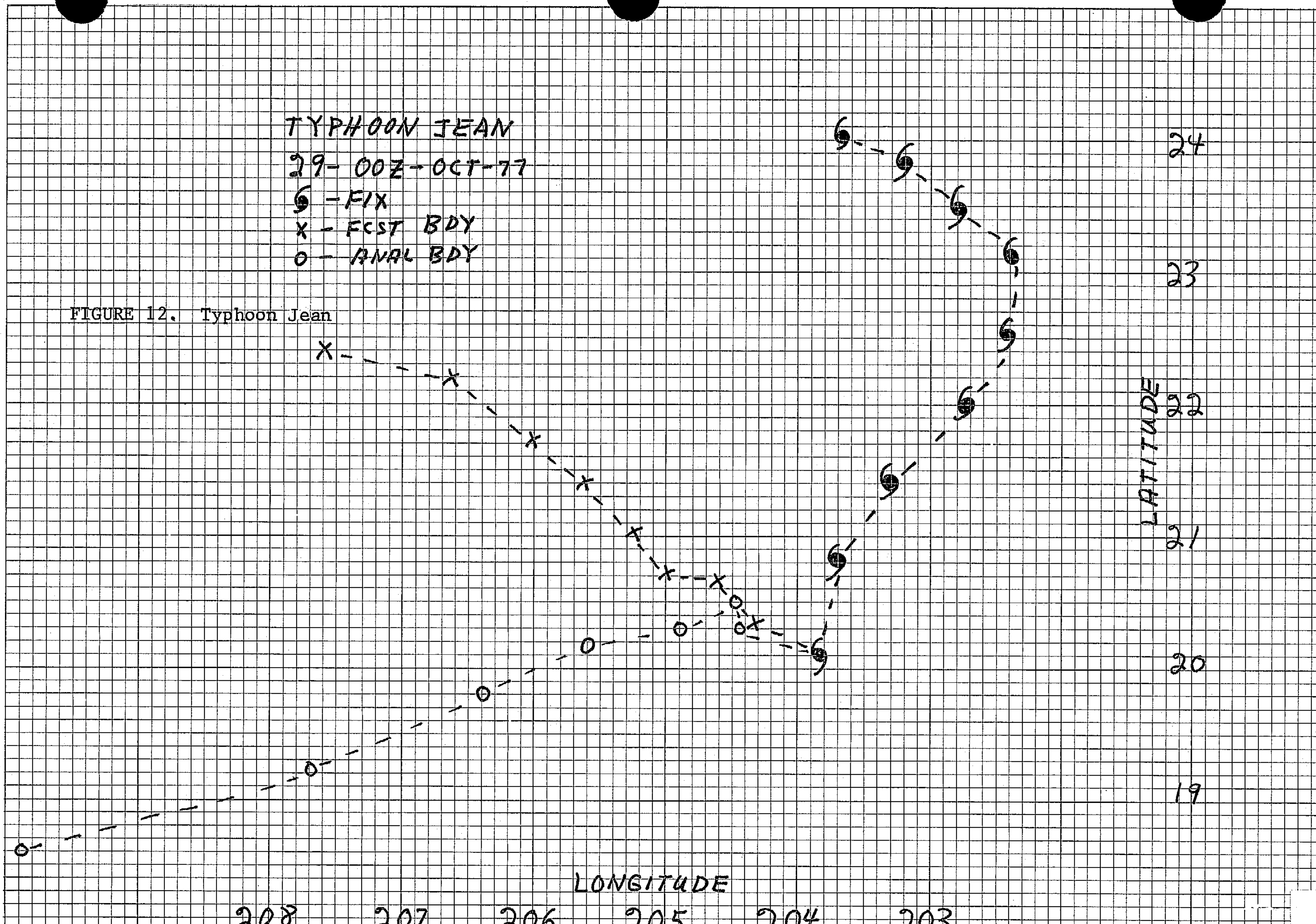

FIGURE 12. Typhoon Jean

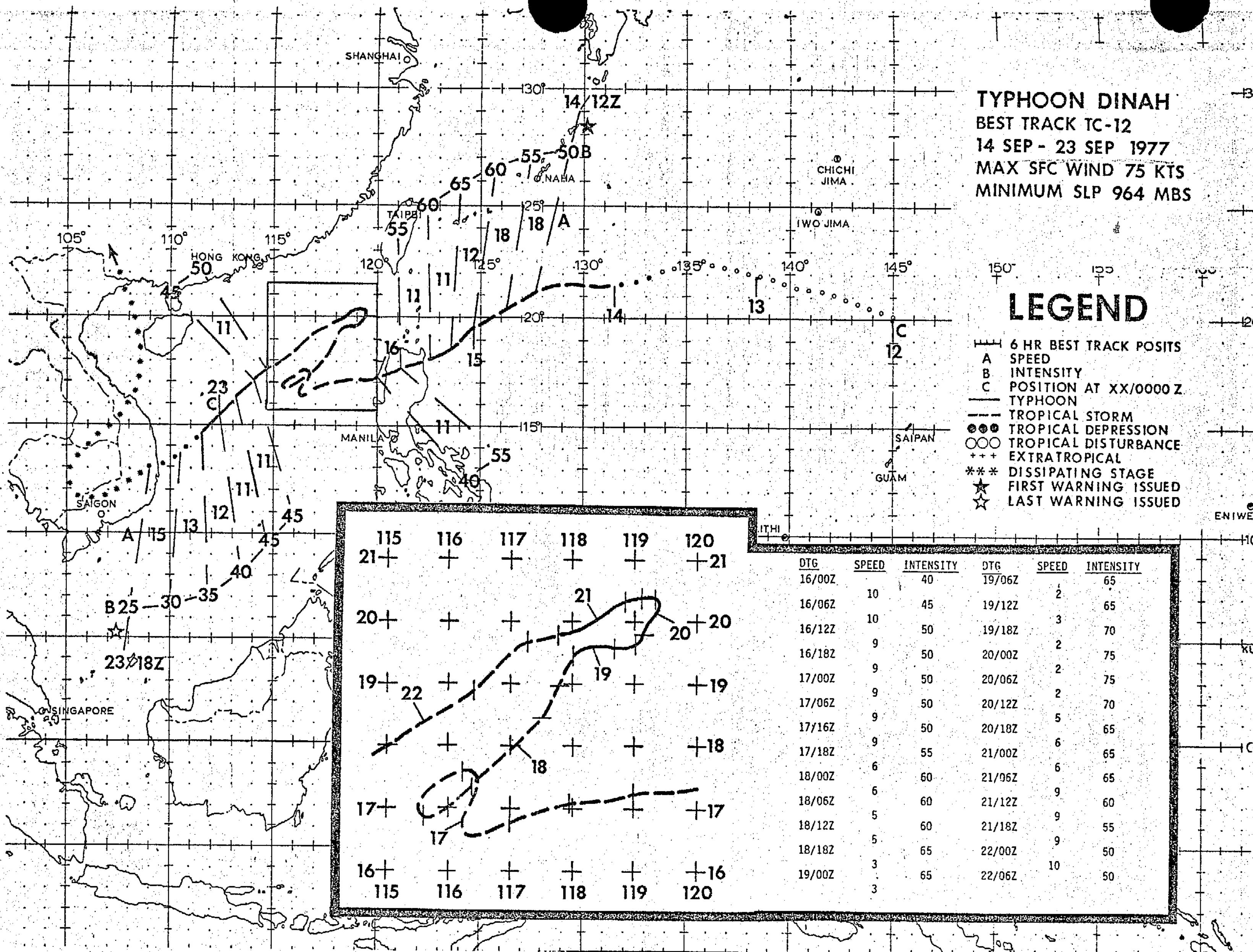

FIGURE 13. (Reference page 30, Annual Typhoon Report - 1977)

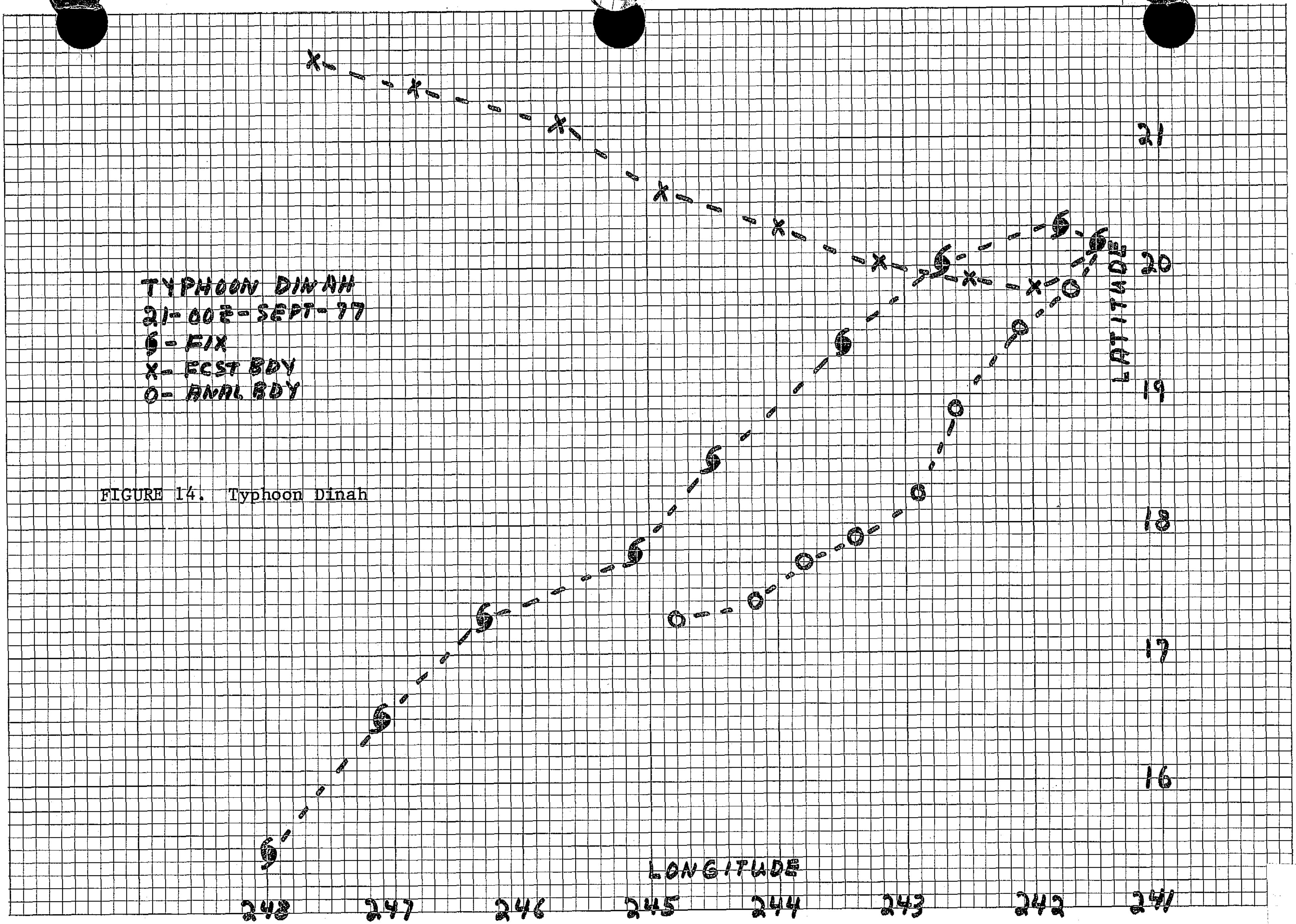

FIGURE 14. Typhoon Dinah